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NATIONAL DEFENSE RESEARCH COMMITTEE
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OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT

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WASHINGTON, D. C.

ADDRESS REPLY TO
2101 CONSTITUTION AVENUE
WASHINGTON, D. C.

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AIR MAIL
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PER DOC REVIEW JAN. 1973
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Dr. J. R. Oppenheimer
P. O. Box 1663
Santa Fe, New Mexico

Dear Robert:

The object of this letter is to report on the calculating machines. I have been in New York, and I discussed the Bell Telephone Relay-Computer with its authors, S. B. Williams and G. R. Stibitz. I have also been in Aberdeen, and discussed there with the head of the machine-computing section, L. E. Cunningham, the promised improved I.B.M. multipliers, and I heard from him and from R. H. Kent, Major Bennett, and Captain Goldstein about the probability of the Army Ordnance Dept. buying a Bell Tel. Relay-Computer. The results are these:

According to the Aberdeen information the Ordnance Dept. will most probably buy one, although it may take 1-2-3 weeks before the letter of intent is sent. It will probably be a 2-computer aggregate.

The information on price and delivery is less favorable: Probably about $80-90,000 and 8 months delivery for a 2-computer aggregate. (Stibitz' unofficial estimate, but probably sound.)

The answer to our technical questions follow below; they are very favorable. My overall impression is that the machine would be well worth having if a future of, say, 1½ years or more is being envisaged for the project. I think that it would not be necessary to make a very great effort to get a branch of the N.D.R.C. interested, particularly if the Ordnance Dept. has already gone ahead in this matter, which seems likely.

The technical details concerning the Bell Tel. Relay-Computer, as well as some details about the improved I.B.M. multiplier (promised to Aberdeen) follow:

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OCT 29, 1979
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Bell Tel. Relay-Computer:

I give the answers to the 21 questions ~~Stanley Frankel and~~ I formulated, and then some general remarks.

1) There exists a very detailed instruction book for the (existing one-purpose) A.A.Board Machine, and a brief report on the proposed all-purpose machine. I will get both.

2) The complete machine is now contemplated to consist of a number of self-contained units, called "computers", which can be used conjointly. 2-, 6-, or 10-computer aggregates are planned, but the chances are that the 2-computer aggregate will be built, since the most serious prospective buyer (Ord. Dept.) asked only for this.

3) Each computer will have 15 registers (= counters) and a special device of its own for each one of these operations: $\pm$, x, :, $\sqrt{}$. Price and delivery: See above.

4) For a register a number x is defined as $x = \pm 10^{n} a$, where $n = -19, -18, \ldots, 19$ (!), and a is between 1 and 0.1, given to 7 significant digits.

5) The counter capacity is as stated in 3), 4). It could be increased with little trouble. An extra unit, containing 15 more registers (and nothing else) might be about $15,000. The increase from 7 to 8 significant units is feasible, and not very bad, but it would have to be general policy if carried out.

6) The operations $\pm$ are not done as in I.B.M's, as part of transfers, but in a separate computing device, the "adder", just like multiplication, division, or square rooting.

An instruction on the control-tape therefore looks like this: "Take the contents of register a, also the contents of register b, add (or subtract, or multiply, etc.), and put the result into register c." At the same time it must be specified, whether the content of a (or b) must be held or cleared after this step. If it is to be cleared, then c may coincide with a (or b).

Stibitz states that a cube rooting device could be added with relative ease.

7) Durations of the main operations in milliseconds:

a) Transfer from register to register: 63 (in the same computer) or 85 (between two separate computers).

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b) $\pm$: In Williams' report rated 378, since improved to 350 or less. (Stibitz).

c) Multiplication: In Williams' report rated 1014, since improved to 800.

d) Division: Similarly 1665 and 1500.

e) Square root: Similarly 3822 and 3500. All this is done to 7 significant digits (see 4)), but within the calculators the 8th digit is carried for rounding-off purposes. (Doesn't this eliminate the desire to carry 8 digits? Cf.5).)

8) Each computer has its typewriter and reperforator (= puncher). Two of each could be provided easily, if desired.

The punched tape is 6 holes wide, a "character" on any tape is therefore a transversal group of 3 holes out of these 6. A character is a decimal digit, or part of a coded instruction.

Punching a character or typing a digit or letter takes 1/6 second.

Reading speed (from tape into a register, or in sensing instructions): One character in 1/20 second.

9) These are the kinds of tapes used:

(a) Problem tape: Carries numerical data, and operational instructions and references to (b), which are specific to the problem considered.

(b) Routine tape: Carries those operational instructions which are common to all problems of a class considered. May refer occasionally to (c).

(c) Auxiliary routine tapes: May be used for frequently recurring sub-cycles within (b). 2 such tapes are contemplated for the entire aggregate, to be assigned as the need arises to the 2 computers. Their number could be increased, if desired.

(d) Table tapes: Containing tabulated functions, for which the machine can "hunt". 3 for each computer.

Further characteristics: (a) and (b) are entirely separate. The machine will probably be able to "hunt" even on (a) for a specified number, if so instructed.

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The machine can use in (a) a tape which comes from the reperforator - i.e., which it has punched itself.

10) The main limit of machine speed is set by the speed of the arithmetical operations. However, there is a definite reading speed on all tapes (a) - (c): One character in 1/20 second, cf. 8).

11) Hunting on the tables tapes (d) goes in both directions, speed again one character in 1/20 second, at least with the present (teletype) equipment - it might be improved later.

12) Each tape must be read by the computer to which it belongs. Then inter-computer register-to-register transfer is possible, cf. 7), a).

The controls are interchangeable between the computers (cf. 8), (c)), but they are never common in operation.

13) Alternate orders may be given, depending upon the sign of a number in a specified counter. (This replaces, and improves on, the I.B.M. "x-selections".)

14) Each character is a group of 3 holes out of 6. These are 20 combinations. On the tapes (a), (d) 10 are used for the decimal digits. In the code for operational orders, an order consists of 5 - 7 such characters. (Typical order: "Take the contents of register a and hold it, take the contents of register b and clear it, multiply, and put the result into register c." Note that the numbers of a, b, c [of which there are 15 in the computer] are part of the order. cf. 6).)

15) The "setting up" of a problem for the machine is almost the same as for human computers. It is punched on the tapes by a special hand-puncher, where the keys show the ordinary algebraical symbols.

The machine times itself, and waits after each step until the required operation is carried out. The routine tape can even look one step ahead, and carry out another operation accordingly, if feasible.

16) The two computers obey their respective routine tapes, cf. (2).

17) 3 or 4 fixed tables are contemplated for the entire machine, common to both computers. Reading speed from a fixed table: 85 milliseconds per function value or interpolation coefficient. (This is an "instantaneous" reading, no "hunting" necessary!) Number of entries per fixed table flexible, about 100 contemplated.

Such a table with 100 entries and 2 interpolation coefficients for each entry would cost about $1500.

The fixed tables are wired in; hand setting with switches might be rather expensive. (For 100 entries, 2 interpolation coefficients, perhaps $10,000.) So they are suited for functions like log x, e^x, sin x, etc.; equations of state, which change from problem to problem, are better put on table tapes.

18) Errors are checked automatically everywhere. Only two, accidentally simultaneous, compensating errors in the same group of 6 holes (one unwanted punch and one failure to punch) could "mislead" the checking circuits. Stibitz denies that any "general" breakdown could ever produce this. The same applies to the punched (output) tape as well, but not to possible errors of the typewriter.

19) If an error is sensed, the machine makes 2 retrials, then rings the alarm. It can be set for "night operation", then it will not ring the alarm but drop the problem instead, and start on another one, if one is available.

The machine gives various indications concerning the seat of the trouble. Average time to locate and repair typical troubles believed to be 10-30 minutes.

Average run between two errors requiring human intervention: On a now running relay-interpolator (5 registers): 1 month. A.A.Board machine: No sufficient experience yet, but it seems likely that it is at least 1 week. (Trouble which adjusts itself automatically [by the 2 retrials]: Perhaps daily. The teletype-equipment needs checking, cleaning, etc., about every 2 weeks.)

20) The same questions for the A.A.Board machine: Cf. 19).

21) Personnel requirements:

Technical supervision: One man, who can supervise human computers.

Maintenance: One man with high school education, plus 1 month's training by Bell Tel. Co.

Crew: A 2 computer aggregate running 24 hours may require 1-3 girls (key punch practice only) to punch in data.

(These personnel requirements seem quite remarkably moderate!)

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Other details:

Power plant: The relays operate on D.C. 50 volts. The primary source should be preferably 60 cycle A.C., 110 volts.

The floor space required for a 2-computer aggregate is 15' x 10'; this room should be air-conditioned in the interest of good relay operation. Operating room 20' x 10', power plant 10' x 10'.

Each computer is mounted on a 10' long and 8' high relay rack.

The relays used function as follows: Heavily loaded relay (12 contacts): Operates in 15, releases in 10 milliseconds. Lightly loaded relay (2 contacts): 9 and 4, correspondingly.

In Cunningham's opinion the simplicity in planning, the reliability of the elements, the self-checking features, and the ability to run overnight without a crew, should alone make the machine 5 times or more faster than any I.B.M. aggregate, quite apart from the other advantages.

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Improved I.B.M. Multiplier:

The timing is based on a new principle: The timing unit is not, as in the ordinary I.B.M's, 1/12 of the card cycle, but 1/48 or 1/96. The machine can be run at two card-feeding speeds: 6000 or 3000 cards per hour, the above mentioned unit being 1/48 or 1/96 of this, respectively. The reading of the cards occurs during the units of 6 to 44. A multiplication takes between 12 and 16 units only on this scale. At the high card feed speed (6000 c.p.h.) 1 multiplication per card cycle is possible; at the low one (3000 c.p.h.) 3 successive or 8 simultaneous multiplications per card cycle. All multiplications are 6-digit ones.

Two card feeds, one with punching and comparing relays also.

No divider, except that Cunningham has a way to wire a multiplier as a divider. This would give here 600 divisions per hour.

18, 6-digit counters. Transfers + or -. Clears counters at any time. (Cf. in particular 3) below.) The controls are threefold:

1) 3 or 4 x-selectors, possibly more.
2) Probably selection by the sign in a specified counter. (Perhaps more than one available.)
3) Main control method: Each one of the 96 (or 48) timing units emits a separate impulse, to which controls can be wired. Combinations of these points can also be used.

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Obviously 3) replaces the blank cards, and gives the machine an enormous flexibility. It is clearly more "intelligent" than any tabulator.

However: The machine does not function yet! The relays were steel-and-brass, which seems to be an unusual and, as it turned out, unsatisfactory arrangement. They had to be taken out and will be replaced by better ones. The functioning is now promised for a month from now. Cunningham thinks that the machine will ultimately work at the specified speeds, but he has little faith in the deadlines.

<u>Important</u>: All data on this multiplier are <u>for domestic use only</u>.

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Please excuse the length of this letter, and about the somewhat off-on-a-tangent subject matter. I plan to write you soon more briefly and more to the main subject. If there are any further questions on calculators, I will be glad to answer them.

With best regards,

Yours,

John

John Von Neumann